

1 SUPPLEMENTARY TABLES

| True model: | - | +G | +I | +G+I | +F | +G+F | +I+F | +G+I+F |
|-----------------------|-----|-----|-----|------|-----|------|------|--------|
| Model Indicator | 100 | 98 | 99 | 98 | 99 | 100 | 100 | 98 |
| has Invariable Sites | 100 | 99 | 100 | 100 | 100 | 98 | 100 | 100 |
| has Gamma Rates | 100 | 96 | 98 | 96 | 100 | 97 | 99 | 100 |
| use External Freqs | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 98 |
| gamma Shape | x | 100 | x | 93 | x | 97 | x | 91 |
| Proportion Invariable | x | x | 95 | 94 | x | x | 94 | 94 |
| Tree Height | 96 | 93 | 91 | 94 | 100 | 94 | 98 | 97 |
| Yule Model | 92 | 88 | 93 | 95 | 98 | 95 | 98 | 98 |
| birth Rate | 93 | 92 | 92 | 92 | 93 | 92 | 92 | 93 |
| frequencies.1 | x | x | x | x | 94 | 94 | 91 | 91 |
| frequencies.2 | x | x | x | x | 93 | 96 | 97 | 95 |
| frequencies.3 | x | x | x | x | 92 | 90 | 91 | 90 |
| frequencies.4 | x | x | x | x | 94 | 94 | 94 | 92 |
| frequencies.5 | x | x | x | x | 93 | 97 | 94 | 93 |
| frequencies.6 | x | x | x | x | 93 | 90 | 94 | 95 |
| frequencies.7 | x | x | x | x | 93 | 97 | 95 | 97 |
| frequencies.8 | x | x | x | x | 94 | 98 | 93 | 96 |
| frequencies.9 | x | x | x | x | 93 | 98 | 95 | 90 |
| frequencies.10 | x | x | x | x | 91 | 92 | 92 | 92 |
| frequencies.11 | x | x | x | x | 98 | 91 | 93 | 92 |
| frequencies.12 | x | x | x | x | 91 | 97 | 94 | 95 |
| frequencies.13 | x | x | x | x | 94 | 92 | 93 | 93 |
| frequencies.14 | x | x | x | x | 95 | 94 | 90 | 94 |
| frequencies.15 | x | x | x | x | 97 | 96 | 96 | 96 |
| frequencies.16 | x | x | x | x | 94 | 94 | 95 | 91 |
| frequencies.17 | x | x | x | x | 99 | 99 | 94 | 94 |
| frequencies.18 | x | x | x | x | 97 | 93 | 95 | 93 |
| frequencies.19 | x | x | x | x | 94 | 95 | 89 | 94 |
| frequencies.20 | x | x | x | x | 96 | 92 | 93 | 96 |

Table S1. As Table 2 but for sequences with length 50 instead of 200, strict clock instead of relaxed clock to simulate data as well as doing inference.

| True model: | - | +G | +I | +G+I | +F | +G+F | +I+F | +G+I+F |
|-----------------------|-----|-----|-----|------|-----|------|------|--------|
| Model Indicator | 99 | 100 | 97 | 99 | 100 | 100 | 99 | 99 |
| has Invariable Sites | 100 | 98 | 100 | 100 | 100 | 98 | 100 | 100 |
| has Gamma Rates | 100 | 96 | 98 | 98 | 100 | 99 | 99 | 100 |
| use External Freqs | 100 | 99 | 100 | 99 | 97 | 100 | 100 | 99 |
| gamma Shape | x | 96 | x | 91 | x | 94 | x | 93 |
| Proportion Invariable | x | x | 95 | 96 | x | x | 97 | 98 |
| Tree Height | 97 | 90 | 94 | 93 | 97 | 92 | 91 | 94 |
| Yule Model | 99 | 91 | 94 | 92 | 97 | 96 | 98 | 95 |
| birth Rate | 94 | 90 | 92 | 93 | 93 | 94 | 91 | 93 |
| uclDStdev | 96 | 98 | 97 | 96 | 96 | 97 | 95 | 97 |
| frequencies.1 | x | x | x | x | 98 | 94 | 93 | 92 |
| frequencies.2 | x | x | x | x | 95 | 95 | 94 | 88 |
| frequencies.3 | x | x | x | x | 91 | 94 | 96 | 96 |
| frequencies.4 | x | x | x | x | 95 | 96 | 89 | 90 |
| frequencies.5 | x | x | x | x | 96 | 95 | 91 | 94 |
| frequencies.6 | x | x | x | x | 97 | 94 | 98 | 95 |
| frequencies.7 | x | x | x | x | 96 | 94 | 94 | 93 |
| frequencies.8 | x | x | x | x | 98 | 95 | 96 | 99 |
| frequencies.9 | x | x | x | x | 90 | 94 | 96 | 91 |
| frequencies.10 | x | x | x | x | 95 | 96 | 93 | 93 |
| frequencies.11 | x | x | x | x | 90 | 95 | 93 | 88 |
| frequencies.12 | x | x | x | x | 94 | 90 | 92 | 95 |
| frequencies.13 | x | x | x | x | 92 | 95 | 93 | 90 |
| frequencies.14 | x | x | x | x | 87 | 91 | 94 | 89 |
| frequencies.15 | x | x | x | x | 95 | 92 | 87 | 92 |
| frequencies.16 | x | x | x | x | 96 | 91 | 96 | 96 |
| frequencies.17 | x | x | x | x | 93 | 95 | 96 | 93 |
| frequencies.18 | x | x | x | x | 93 | 95 | 94 | 88 |
| frequencies.19 | x | x | x | x | 93 | 91 | 94 | 92 |
| frequencies.20 | x | x | x | x | 92 | 94 | 92 | 97 |

Table S2. As Table 2 but for sequences with length 50 instead of 200, strict clock instead of relaxed clock to simulate data, but relaxed clock to infer model.

| True model: | - | +G | +I | +G+I | +F | +G+F | +I+F | +G+I+F |
|-----------------------|-----|-----|-----|------|-----|------|------|--------|
| Model Indicator | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| has Invariable Sites | 100 | 99 | 100 | 100 | 100 | 98 | 100 | 100 |
| has Gamma Rates | 100 | 98 | 100 | 99 | 100 | 98 | 99 | 99 |
| use External Freqs | 100 | 100 | 100 | 99 | 100 | 100 | 99 | 100 |
| gamma Shape | x | 96 | x | 91 | x | 94 | x | 98 |
| Proportion Invariable | x | x | 91 | 96 | x | x | 97 | 94 |
| Tree Height | 97 | 95 | 93 | 97 | 97 | 98 | 96 | 97 |
| Yule Model | 96 | 93 | 94 | 95 | 96 | 100 | 98 | 94 |
| birth Rate | 92 | 93 | 91 | 92 | 92 | 93 | 93 | 92 |
| uclDStdev | 96 | 98 | 97 | 97 | 96 | 97 | 97 | 96 |
| frequencies.1 | x | x | x | x | 92 | 95 | 97 | 91 |
| frequencies.2 | x | x | x | x | 92 | 95 | 91 | 94 |
| frequencies.3 | x | x | x | x | 95 | 92 | 94 | 96 |
| frequencies.4 | x | x | x | x | 92 | 94 | 91 | 93 |
| frequencies.5 | x | x | x | x | 94 | 95 | 95 | 95 |
| frequencies.6 | x | x | x | x | 93 | 94 | 93 | 91 |
| frequencies.7 | x | x | x | x | 95 | 95 | 95 | 95 |
| frequencies.8 | x | x | x | x | 92 | 96 | 96 | 93 |
| frequencies.9 | x | x | x | x | 92 | 97 | 96 | 95 |
| frequencies.10 | x | x | x | x | 97 | 92 | 93 | 94 |
| frequencies.11 | x | x | x | x | 95 | 94 | 94 | 89 |
| frequencies.12 | x | x | x | x | 92 | 92 | 93 | 93 |
| frequencies.13 | x | x | x | x | 88 | 93 | 96 | 94 |
| frequencies.14 | x | x | x | x | 95 | 94 | 93 | 95 |
| frequencies.15 | x | x | x | x | 92 | 96 | 95 | 96 |
| frequencies.16 | x | x | x | x | 96 | 91 | 98 | 91 |
| frequencies.17 | x | x | x | x | 92 | 92 | 92 | 93 |
| frequencies.18 | x | x | x | x | 90 | 92 | 94 | 96 |
| frequencies.19 | x | x | x | x | 94 | 91 | 94 | 93 |
| frequencies.20 | x | x | x | x | 95 | 92 | 93 | 89 |

Table S3. As Table 2 but for sequences with length 50 instead of 200.

| True model: | - | +G | +I | +G+I | +F | +G+F | +I+F | +G+I+F |
|-----------------------|-----|-----|-----|------|-----|------|------|--------|
| model indicator | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 100 |
| has invariable sites | 100 | 98 | 98 | 100 | 100 | 97 | 100 | 100 |
| has gamma rates | 100 | 98 | 99 | 97 | 100 | 99 | 99 | 99 |
| use external freqs | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| gamma shape | x | 93 | x | 91 | x | 92 | x | 95 |
| proportion invariable | x | x | 93 | 89 | x | x | 94 | 89 |
| tree height | 94 | 91 | 90 | 96 | 91 | 92 | 94 | 94 |
| Yule model | 93 | 90 | 93 | 97 | 93 | 94 | 96 | 95 |
| birth rate | 92 | 93 | 92 | 92 | 93 | 92 | 92 | 92 |
| UCLD stdev | 96 | 96 | 97 | 96 | 95 | 94 | 97 | 97 |
| frequencies.1 | x | x | x | x | 96 | 95 | 93 | 94 |
| frequencies.2 | x | x | x | x | 95 | 96 | 97 | 94 |
| frequencies.3 | x | x | x | x | 92 | 92 | 91 | 92 |
| frequencies.4 | x | x | x | x | 95 | 96 | 92 | 96 |
| frequencies.5 | x | x | x | x | 96 | 97 | 94 | 94 |
| frequencies.6 | x | x | x | x | 94 | 95 | 93 | 92 |
| frequencies.7 | x | x | x | x | 94 | 95 | 98 | 94 |
| frequencies.8 | x | x | x | x | 96 | 95 | 96 | 95 |
| frequencies.9 | x | x | x | x | 95 | 95 | 95 | 89 |
| frequencies.10 | x | x | x | x | 96 | 95 | 97 | 97 |
| frequencies.11 | x | x | x | x | 95 | 89 | 97 | 94 |
| frequencies.12 | x | x | x | x | 96 | 96 | 97 | 92 |
| frequencies.13 | x | x | x | x | 92 | 94 | 95 | 94 |
| frequencies.14 | x | x | x | x | 95 | 94 | 97 | 93 |
| frequencies.15 | x | x | x | x | 95 | 95 | 93 | 98 |
| frequencies.16 | x | x | x | x | 93 | 98 | 96 | 92 |
| frequencies.17 | x | x | x | x | 93 | 95 | 96 | 95 |
| frequencies.18 | x | x | x | x | 95 | 96 | 94 | 93 |
| frequencies.19 | x | x | x | x | 95 | 93 | 95 | 95 |
| frequencies.20 | x | x | x | x | 98 | 90 | 94 | 98 |

Table S4. As Table 2 but prior on gamma shape not truncated at 0.1.

| True model: | - | +G | +I | +G+I | +F | +G+F | +I+F | +G+I+F |
|-----------------------|-----|-----|-----|------|-----|------|------|--------|
| Model Indicator | 100 | 100 | 99 | 100 | 98 | 99 | 100 | 99 |
| has Invariable Sites | 100 | 99 | 100 | 100 | 100 | 99 | 100 | 100 |
| has Gamma Rates | 100 | 97 | 100 | 98 | 100 | 98 | 96 | 97 |
| use External Freqs | 100 | 99 | 98 | 100 | 99 | 100 | 100 | 99 |
| gamma Shape | x | 98 | x | 91 | x | 97 | x | 93 |
| Proportion Invariable | x | x | 93 | 92 | x | x | 95 | 93 |
| Tree Height | 96 | 96 | 97 | 94 | 94 | 94 | 98 | 99 |
| Yule Model | 90 | 95 | 92 | 91 | 94 | 95 | 99 | 96 |
| birth Rate | 97 | 96 | 96 | 96 | 95 | 96 | 96 | 95 |
| uclDStdev | 95 | 94 | 99 | 94 | 93 | 95 | 92 | 97 |
| frequencies.1 | x | x | x | x | 96 | 96 | 93 | 98 |
| frequencies.2 | x | x | x | x | 91 | 96 | 99 | 99 |
| frequencies.3 | x | x | x | x | 95 | 88 | 92 | 94 |
| frequencies.4 | x | x | x | x | 95 | 97 | 93 | 96 |
| frequencies.5 | x | x | x | x | 96 | 96 | 96 | 94 |
| frequencies.6 | x | x | x | x | 93 | 94 | 93 | 96 |
| frequencies.7 | x | x | x | x | 92 | 95 | 93 | 92 |
| frequencies.8 | x | x | x | x | 96 | 95 | 91 | 94 |
| frequencies.9 | x | x | x | x | 95 | 97 | 97 | 94 |
| frequencies.10 | x | x | x | x | 95 | 96 | 91 | 92 |
| frequencies.11 | x | x | x | x | 90 | 94 | 92 | 92 |
| frequencies.12 | x | x | x | x | 94 | 93 | 90 | 93 |
| frequencies.13 | x | x | x | x | 98 | 92 | 96 | 96 |
| frequencies.14 | x | x | x | x | 96 | 92 | 96 | 93 |
| frequencies.15 | x | x | x | x | 92 | 95 | 96 | 95 |
| frequencies.16 | x | x | x | x | 96 | 93 | 94 | 95 |
| frequencies.17 | x | x | x | x | 98 | 96 | 95 | 93 |
| frequencies.18 | x | x | x | x | 95 | 95 | 94 | 94 |
| frequencies.19 | x | x | x | x | 97 | 94 | 94 | 95 |
| frequencies.20 | x | x | x | x | 96 | 97 | 96 | 92 |

Table S5. As Table 2 but with sequences of length 50.